TCP Improvement in Multi-radio Multi-channel Multi-hop Networks

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ABSTRACT

In this paper, we seek to enhance the poor performance of original TCP in wireless multi-hop environments due to the intra-flow contention between TCP-DATA and TCP-ACK packets. Assuming multi-radio multi-channel networks, where each station is equipped with multiple radios and the same number of orthogonal channels, we propose to use virtually different paths with different channel assignments for TCP-DATA and TCP-ACK transmissions. Simulations show that TCP performance can be improved significantly since TCP-DATA and TCP-ACK paths hardly interfere with each other.

Keywords

TCP, Multi-radio, Multi-channel, Multi-hop Networks

1. INTRODUCTION & MOTIVATION

Wireless multi-hop networking technology is rapidly becoming popular recently. However, TCP cannot adapt to wireless environments well since wireless links have different characteristics like broadcast medium, fading and shadowing problems, limited bandwidth and power. As we investigate, during TCP transmissions in wireless multi-hop networks, a substantial portion of the TCP-ACK packets get lost, and unnecessary TCP retransmissions are triggered. This is mainly because TCP-DATA packets and TCP-ACK packets are transmitted through the same path but in opposite directions, which leads to many intra-flow contentions and collisions. It is very challenging to improve TCP performance over wireless networks and a significant amount of works are carried out. Some proposals use multi-radio multi-channel technique, which helps stations equip multiple radios with multiple non-overlapping channels, so channel contention and interference can be dramatically decreased. BIMCMAC[1] is designed to improve TCP utilizing multiple channels, but their approach is based on single radio, therefore the improvement is limited. We propose a new solution for TCP improvement for multi-radio multi-channel multi-hop networks. Virtually different paths with different channel assignments for TCP-DATA and TCP-ACK flows are made respectively at network layer to improve TCP performance. To our knowledge, this is the first work for TCP improvement in wireless multi-radio multi-channel multi-hope networks.

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2. PROPOSE SOLUTION

2.1 Key Idea

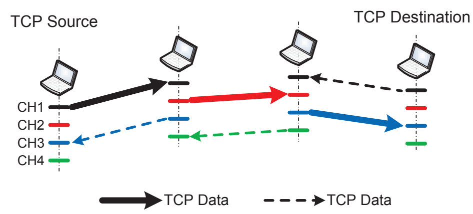


Figure 1: Proposed TCP Transmission

First, we assume that: (1) The network is homogeneous. Every station is equipped with the same number of radios as orthogonal channels; (2) Every flow is unidirectional. Fig.1 illustrates how TCP packets will be handled by our scheme. Each station has four radios, each of which uses one of four orthogonal channels, say, from CH1 to CH4 depicted by different colors. Solid arrows show TCP-DATA transmissions, and dashed arrows are for TCP-ACK. For example, the source uses radio 1 (CH1) to transmit TCP-DATA packets to the second station. Then the second station will relay them to the third station through radio 2, and so on. Then the destination will transmit back TCP-ACK over radio 1 at the first hop, and radio 4 at next hop. If we can keep this strategy as far as possible, intra-flow contentions and collisions will be substantially reduced.

2.2 Channel Selection and Routing

We take a greedy routing approach based on AODV. Each station stores which radios (or channels) are currently used by itself, as well as that information of its one-hop neighbors in the radio status table as illustrated in Fig.2. Each station will periodically exchanged this table with one-hop neighbors by Hello messages. From the collected radio information, a station can know the usage of radios by itself and one-hop neighbors, and then select the least used (or locally optimized) radio for TCP packet transmissions.

Node Id	Relationship	Channel Usage List
4	Itself	00101…
2	Neighbor	11001…
7	Neighbor	01100…
Total Channel Usage Index		12202…

Ch#1	Ch#2	Ch#3	Ch#4	Ch#5 …
0	0	1	0	1 …

1 ~ Occupied by TCP flow
0 ~ Idle

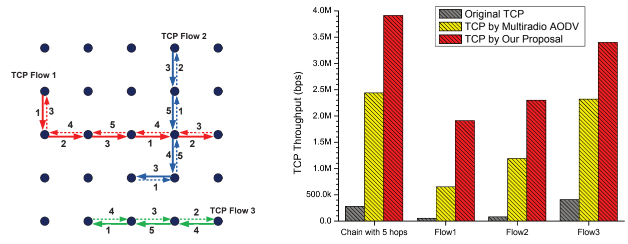
Figure 2: Radio Status Table

Initially the source selects the least used radio and broadcasts an RREQ over the selected radio. Then its one hop neighbors will rebroadcast the RREQ through their least used radios. If the number of radios is sufficient, each station will select the channel that is different form the channels used by the last two hops, in order to avoid the intra-path collisions. All the related information, including the last hop, input radio, output radio, is stored in the routing table. The destination will reply an RREP backwards to the source once it receives an RREQ. While the RREP packet is being relayed over the same route in the opposite direction of the RREQ packet, each intermediate station again selects the least used radio to relay the RREP, which must be different from the radio used when the RREQ is relayed. If possible, the radio for the RREP should be different from the last two hops of the RREP path. The related information is recorded in another entry in the routing table. Note that TCP-DATAs and TCP-ACKs will be relayed over different channels (Hence we propose to use different "paths.").

3. PERFORMANCE EVALUATION

3.1 Network with Light Load

We evaluate our proposal by QualNet4.5 using IEEE 802.11a by selecting 5 channels out of 12 orthogonal ones at each station. That is each station has 5 radios. We first evaluate the chain topology with one TCP traffic and no background traffic. Our proposal is compared with TCP by AODV and by Multi-radio AODV[2]. From in Fig.3(b), our scheme improve TCP throughput significantly. Then we test another scenario in the grid topology with three TCP flows, and the radio selection by our proposal is shown in Fig.3(a). From the results in Fig.3(b), TCP based on AODV performs poorly, and TCP by Multi-radio AODV performs better. Our scheme exploits the multiple radios, and achieves dramatically higher TCP throughput .



(a) Grid Topology (b) Results

Figure 3: Simulation Results

3.2 Network with Heavy Load

In lightly-loaded wireless network, radio resources can be readily utilized by our scheme, and significant TCP improvement can always be achieved. In heavily-loaded network, how much performance gain can be achieve by our scheme is under investigation. We conjecture that our proposal can still achieve better performance since it always optimally chooses the least used radios for transmissions based on current radio usage status of the station and that of the one hop neighbors.

4. CONCLUSIONS & FUTURE WORK

In this paper, we improve TCP performance in wireless multi-radio multi-channel multi-hop networks by differentiating TCP-DATA and TCP-ACK packets using different channels (or "paths") at NWK layer to reduce intra-flow contentions and collisions. Our simulations exhibit that the proposal improves TCP throughput significantly. Comprehensive experiments are under way, especially for heavily-loaded networks. Also, we will consider the relationships among the number of radios, number of channels and the traffic load.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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